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VEGETATION DENSITY AND CARBON STOCK ESTIMATION BY USING NDVI IN THE CORE ZONE AT MOUNTAIN HALIMUN-SALAK NATIONAL PARK

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Abstract

The increase of the greenhouse gas emissions concentrations causes climate change and global warming. Mount Halimun-Salak National Park (TNGHS) has high potential in mitigating CO_2 gas emissions through increasing carbon stock. This study aims to estimate vegetation density using the Normalized Difference Vegetation Index (NDVI), estimate biomass and carbon stock, as well as, analyze the relationship between NDVI and vegetation diversity and carbon stock in the core zone of TNGHS. The method used was vegetation analysis, while carbon estimation used an allometric and destructive approach for the seedling and understory levels. Fifteen plots with a 15 m x 15 m area were used in this study. Based on the results of NDVI analysis, density classes were divided into three classes; class 1 (0.147-0.276), class 2 (0.276-0.321), and class 3 (0.321-0.493). The vegetation composition in the TNGHS core zone consists of 82 plant species from 53 families. The most abundant families are Euphorbiaceae, Lauraceae, Moraceae, Rubiaceae, and Urticaceae. The research location was dominated by African wood (*Maesopsis eminii*). The average biomass and carbon concentration based on density class obtained were 124.46 tonnes/ha and 58.50 tonnes/ha respectively. Carbon concentration had a strong correlation with Basal Area (BA) (r = 68.9%). NDVI values were positively correlated and could be used to estimate the number of species, tree density, Shannon-Wiener index, BA, and carbon concentration.

Keywords: Aboveground Carbon Indonesia's, FOLU Net Sink, Index Vegetation, Area Conservation

INTRODUCTION

Carbon stock estimation refers to the process of quantifying the amount of carbon dioxide (CO2), a greenhouse gas, stored in various ecosystems such as forests, grasslands, wetlands, and agricultural lands. Accurate estimation of carbon stocks is crucial for understanding the role of different ecosystems in the global carbon cycle and for implementing effective carbon management strategies. It provides valuable information for land-use planning, forest conservation, and climate change mitigation efforts.

Carbon stocks are estimated by measuring the biomass (organic matter) present in a given ecosystem. Biomass estimation is the first step to know the carbon content stored in a single tree or the whole forest ecosystem (Istomo et al. 2017). This includes living vegetation such as trees and plants, as well as dead organic matter like fallen leaves, branches, and roots. Additionally, carbon stocks also include carbon stored in soil and organic matter in wetlands (Dewantoro and Jatmiko 2021; Banuwa et al. 2019; Febiriyanti et al. 2021). There are various methods and techniques used for carbon stock estimation, ranging from ground-based measurements such as field sampling and tree inventory, to remote sensing technologies like

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satellite imagery and LiDAR. These approaches provide data that can be used to estimate carbon stocks at different spatial scales, from individual trees to large forested landscapes. Accurate carbon stock estimation is essential for monitoring changes in carbon storage over time, evaluating the impact of land-use changes and disturbances on carbon stocks, and assessing the effectiveness of carbon sequestration projects. It also helps in identifying areas of high carbon density and prioritizing conservation efforts in order to maximize carbon sequestration potential.

Increasing concentrations of greenhouse gas emissions have become a global issue that causes climate change and global warming. Indonesia is one of the countries that contributes the largest greenhouse gases from human activities, deforestation and excessive exploitation of wood forest products (Novarianto 2017).

The effort to mitigate carbon emissions can be carried out through absorption and storage of carbon by forest vegetation in the form of biomass in stands, litter, and other soil organic matter. Indonesia's FOLU Net Sink 2030 is a form of Indonesia's commitment in efforts to mitigate CO_2 gas by making the forestry and other land uses (FOLU) sector as an important component in its low-carbon development strategy and climate resilience, namely through a target level of absorption of equal or greater than the emission level in 2030. The net sink target set is 140 million tons of CO_2 in 2030. Forestry and Other Land Uses (FOLU) including the agroforestry sector is one of the important sectors as a strategy for climate resilience and low-carbon development in Indonesia (Hartoyo APP *et al.* 2022).

Mount Halimun-Salak National Park (TNGHS) is the one of the conservation areas with a high biodiversity. In general, the vegetation in TNGHS is dominated by *Weinmannia blumei*, *Castanopsis argentea*, *Schima wallichii*, and *Altingia excelsa.* Apart from that, TNGHS is also a habitat for endemic species such as *Panthera pardus*, *Hylobates moloch*, and *Spizaetus bartelsi.* Endemic species in TNGHS are generally found in zones far from community settlements such as the core zone (BTNGHS 2021). The core zone is an area that functions as a regulator of water management and nutrient cycles as well as a carbon storage area. Any changes due to degradation and deforestation in the core zone could disrupt carbon absorption and the opening of the forest canopy.

Monitoring forest canopy and vegetation density can be conducted through the remote sensing method by using the approach of Normalized Difference Vegetation Index (NDVI). NDVI uses green spectral reflectance values to divide vegetation density classes as an indicator of the quality of forests and vegetated areas. The study used the spatial analysis in TNGHS are still limited, hence, more research is needed to carry on to observe the role of TNGHS in the action of change climate mitigation by using spatial approach.

Objective Study:

This study aims to estimate the vegetation density and diversity by using the NDVI approach, estimating the potential biomass and above ground carbon stock, as well as to analyze the connection NDVI with number of species, number of individuals tree, diversity type, basal areas (BA), and carbon storage in the core zone, Resorts Mountain Salak I, TNGHS.

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Benefit Study:

This study was expected to give the information regarding vegetation density, species diversity, and carbon stock in TNGHS so that could be used as the basis for taking decision by the management of TNGHS. The research results could be used as a TNGHS database related to mitigation actions towards Indonesia's FOLU Net Sink 2030.

MATERIALS AND METHODS

Time and Location

This study was conducted on October to December 2022. The location of study was at the core zone, Gunung Salak I Resort, Mount Halimun-Salak National Park, located in Village Tamansari and Village Sukamantri, Bogor Regency. Data analysis was carried out in Laboratory Ecology Forest, Faculty Forestry and Environment, IPB University.

Tools and Materials

Tools were used in this study includes GPS, compass, tape measuring, tape diameter, machete, stationery, haga hypsometer, camera, digital scale, oven, Microsoft Office Word, Microsoft Office Excel, ArcMap 10.8, SPSS, and Avenza application software. The materials were used include tally sheet, trash bag, plastic ziplock, A3 envelope, and the vegetation in Tamansari Village and Village core zones Sukamantri, Resorts Mountain Salak 1, TNGHS.

Procedure Study

This study consists of five stage implementations, namely making the map of the vegetation density classification using NDVI, making sample plots, measuring the species composition and structure of tree stands, measuring the above ground biomass and carbon stocks, as well as data analysis. The procedure of this study was as follows:

1. Making the map of vegetation classification and density using NDVI

Making map vegetation density was carried out by using the Normalized approach Difference Vegetation Index (NDVI). Landsat 8 OLI/TIRS Level 2 with UTM 48S and path/row 122/065 downloaded on March 27th 2022 was used for the satellite image. Making NDVI map was done on ArcMap 10.8 with the classification of density class become 3 classes, namely low, medium and high.

2. Making the sample plots

The single plot was constructed by using the stratified random sampling method. Five plots for each class density were used in this study. A plot with 50 m × 50 m in size was used for trees. Subplots 10 m × 10 m in size were used for poles, 5 m × 5 m for saplings, and 2 m × 2 m for seedlings and understory (Figure 1).

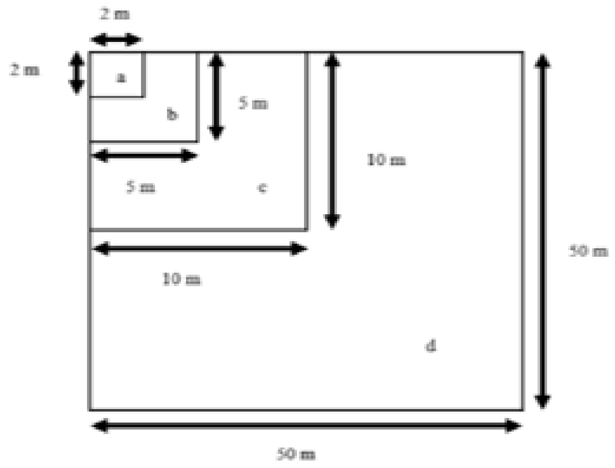

Figure 1: Vegetation analysis plot

The plot size of 50 m x 50 m was bigger than the Landsat image pixel size (30 meters). It was due to the obtained data could be more representative than using a plot area which were smaller than the pixel size of the Landsat image (Suwargana 2013).

3. Measuring the Species Composition and Structure of Tree Stands

Collecting primary data on the number of living plants, height and diameter in natural stands in the core zone of TNGHS followed the criteria of Hidayat and Hardiansyah (2012), namely the growth rate of seedlings (height of <1.5 m), saplings (height of >1 .5 m for young trees with a diameter of <10 cm), poles (young trees with a diameter of 10 to 20 cm), and for mature trees (diameter >20 cm).

4. Measurement of Aboveground Biomass and Carbon Stocks

Sampling was conducted to calculate the biomass of understory and seedlings was carried out destructively. The understory and seedlings in the 2 m × 2 m subplot were taken without the roots and then the total wet weight (WWt) was calculated. Samples were weighed 200-300 grams (WWs) to be dried in an oven at 800 C for 48 hours (BSN 2011). The result of measuring the weight of the dried sample was judged as the furnace dry weight (WDs). The estimation of standing biomass and carbon stocks was carried out using non-destructive methods. Vegetation at the sapling, pole and tree stage were measured using total height and diameter breast high (DBH) to estimate the stand biomass using allometric equations.

5. Data analysis

a) Importance Value Index

The Important Value Index (INP) was used to determine the dominance of one species over another. According to Soerianegara and Indrawan (1988), density (D), relative density (RD), frequency (F), relative frequency (RF), dominance (D), relative dominance (D), relatif

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deominance (RD) and important value index (IVI) can be calculated using the following formula:

$$D = \frac{\sum Individual\ of\ a\ species}{Sample\ plot\ area}$$

$$RD = \frac{\sum Density\ of\ a\ species}{density\ of\ all\ species} \times 100\%$$

$$F = \frac{\sum The\ plot\ found\ a\ species}{\sum All\ sample\ plot}$$

$$RF = \frac{Frequency\ of\ a\ species}{Frequency\ of all\ species} \times 100\%$$

$$D = \frac{Total\ basal\ area\ of\ a\ species}{Plot\ sample\ area}$$

$$RD = \frac{Density\ of\ a\ species}{Density\ of\ all\ species} \times 100\%$$

IVI (seedlings and saplings) = RD+RF

IVI (trees and poles) = RD+RD+RD

b) Species Diversity Index (H'), Species Dominance Index (C), Species Richness Index (R), and Species Evenness Index (E)

Calculation of H' and R values refers to Margalef (1972). Species dominance index (C) refers to Simpson (1949). Calculation of the species evenness index refers to Magurran (2004).

c) Calculation of Understory and Seedling Biomass

Destructive methods were used to measure understory and seedling biomass. Measurements were carried out by harvesting all understory and seedlings without the roots.

$$WDt = \frac{WDs}{WWs} \times WWt$$

Information:

WDt = Weight Dry total (kg)

WWt = Total Wet Weight (kg)

WWs = Wet weight of sample (kg)

WDs = Weight Dry sample (kg

d) Standing Biomass Calculation

Standing forest biomass was estimated using allometric equations. The allometric equations are presented in Table 1.

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Table 1: Allometric model

Type	Model Allometric
Mixture	AGB = ρ × exp(-1.499 + 2,148ln(D) + 0.207(ln(D)) ^{2} - 0.0281(ln(D)) ^{3}) [a]

[a] Source: Chave et al. (2005)

e) Estimation of Carbon Stocks

The biomass value from the calculation results was used to estimate the potential for stored carbon. Carbon content can be determined by using the carbon fraction of forest biomass, namely 0.47.

$C = B \times 0.47$

(IPCC 2006)

Information:

C = Carbon stored (tons/ha)

B = Biomass (tons/ha)

f) Classic assumption test

The classical assumption test was carried out using the normality test and heteroscedasticity test. Normality test Shapiro-Wilk was conducted to ensure that the research data was normally distributed. The heteroscedacity test was carried out using the Glejser method to investigate the inequality of the residual variance of one observation to another observation.

g) Correlation Test

The aim of the correlation test was to measuring the closeness of the relationship between the independent variable and the dependent variable. Pearson correlation test chosen because the test carried out was a parametric statistical test on data that was normally distributed and did not occur heteroscedasticity.

h) Regression Test

The regression test was carried out to measure the magnitude of the influence of the independent variable on the dependent variable. The regression model used was simple linear regression.

i) Model Validity Test

The model validity test aims to estimate the accuracy of an estimation model. Testing the accuracy of the estimation model refers to Muhammad (2014).

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RESULTS AND DISCUSSION

Vegetation Density in the TNGHS Core Zone

Estimation of vegetation density was carried out using the Normalized Difference Vegetation Index (NDVI) which produces three vegetation classes. The results of the one vegetation density class is presented by one color. Purwanto (2015) stated that the land with a high level of vegetation density is shown by a darker color (green) because of the high reflection of light produced by the vegetation. The range of NDVI values for each class divided based on the Natural Breaks (Jenks) classification method is presented in Table 2.

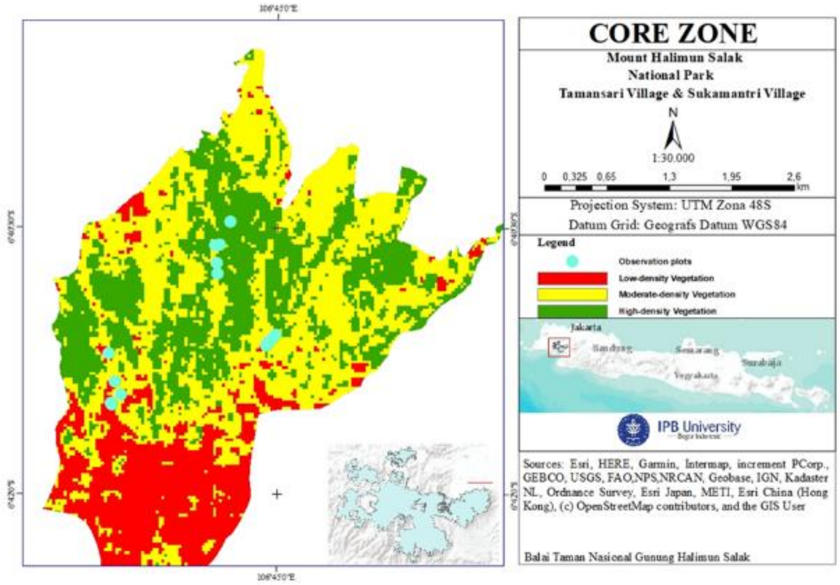

Figure 2: NDVI map in the core zone TNGHS

The NDVI values produced in the three density classes are in the range of 0.147 to 0.439. This value range is above 0 indicates that the three classes can be classified as vegetated areas. Yurianda et al. (2022) stated that the areas with NDVI values below 0 are included in the non-vegetation areas (water bodies, clouds or snow).

Table 2: NDVI values for each density class

Class	NDVI value	Vegetation Density
1	0.147 – 0.276	Low
2	0.276 – 0.321	Currently
3	0.321 – 0.493	Tall

Vegetation Composition

Vegetation composition is shown through the arrangement and number of vegetation types. Vegetation analysis, which carried out on 15 plots with a total area of 3.75 ha, showed that there were 82 plant species from 53 families. The families most commonly found are Euphorbiaceae, Lauraceae, Moraceae, Rubiaceae with 5 species each and Urticaceae with 4

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species. The current domination of the species are competent and be able to efficiently use the resources with better adaptation to the environmental factors changes throughout the times (). The number of types found is presented in Table 3.

Table 3: Number of species

Growth rate	Number of species		
	class 1	grade 2	grade 3
Understory [a]	19	13	24
Seedling	10	12	24
Stake	6	6	8
Pole	7	5	7
Tree	10	14	13
Number of types	36	30	55
All three classes	82		

*Not included in growth rate

Table 3 indicates the species in each density class. Density class with the most species were found in class 3 (tall), with 24 species of understory plants and 31 species of woody plants. This shows that land with a higher vegetation density has more diverse vegetation growth. Arifanti et al. (2014) stated that submontane forests have higher biodiversity than plants in the montane forest type. Importance index describing the stability of a species to maintain its growth and sustainability. A tree-level species must have an IVI value ≥ 15% to be judged to play a role in the ecosystem. The species with the highest IVI values in each class are presented in Table 4 - 6. The species has the highest IVI value at each growth stage which indicates that the species has an important role in that area (Istomo et al. 2020).

Table 4: Three highest IVI values in class 1

Growth rate	Scientific name	IVI (%)
Understory*	*Asplenium belangeri*	27.25
	Piper aduncum L.	22.17
	Pandanus tectorius	20.72
Seedling	*Syzygium lineatum*	49.35
	Brassaiopsis speciosa	29.84
	Macaranga triloba	26.40
Sapling	*Schima wallichii*	66.91
	Cinnamomum burmannii	36.03
	Macaranga triloba	30.15
Pole	*Symplocos fasciculate*	75.91
	Weinmannia blumei	53.87
	Schima wallichii	48.89
Tree	*Schima wallichii*	72.82
	Syzygium lineatum	58.50
	Weinmannia blumei	50.53

*Not included in growth rate

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Table 5: Three highest IVI values in class 2

Growth rate	Scientific Name	IVI (%)
Understory*	*Oplismenus hirtellus*	40.07
	Clidemia hirta	30.66
	Asplenium belangeri	30.62
Seedling	*Altingia excelsa*	33.04
	Symplocos fasciculate	32.78
	Maesopsis eminii	28.96
Sapling	*Calliandra calothyrsus*	66.67
	Cinnamomum burmannii	38.10
	Altingia excelsa	23.81
Pole	*Cinnamomum burmannii*	127.34
	Schima wallichii	56.38
	Caesia dehaasia	52.65
Tree	*Schima wallichii*	71.50
	Maesopsis eminii	46.91
	Cinnamomum burmannii	35.78

*Not included in growth rate

Table 6: Three highest IVI values in class 3

Growth rate	Scientific name	IVI (%)
Understory*	*Hedyotis corymbosa*	22.78
	Piper aduncum L.	21.00
	Cycas rumphii	15.56
Seedling	*Maesopsis eminii*	62.55
	Magnolia macklottii	18.74
	Symplocos fasciculate	13.66
Sapling	*Symplocos fasciculate*	63.75
	Homalantus populneus	32.50
	Artocarpus elasticus	22.50
Pole	*Trema orientalis*	62.99
	Homalantus populneus	48.48
	Radermachera glandulosa	41.06
Tree	*Maesopsis eminii*	198.74
	Trispermic aleurites	14.25
	Homalantus populneus	12.29

*Not included in growth rate

Based on Table 4-6, the understory plants that have the highest IVI in all classes are basket grass (*O. hirtellus*) and sesereuhan/ forest betel leaf (*P. aduncum)*. Basket grass and sesereuhan are invasive species with high vegetative reproduction capabilities. These invasive species generally invade forest areas with woody tree canopies. There are several types of natural regeneration that dominate the three density classes is indicated by the species of African wood at the seedling level and the species of Puspa at the sapling level. According to Sari (2017), the species that can be used as the location markers that is still classified as primary forest are the growth of the puspa (*S. wallichii*) and rasamala (*A. excelsa*). The native plant species colonize

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more to the degraded areas than exotic species, but have lower survival abilities than some exotic species. The difference in the ability of a species to adapt to its environment is thought to be closely related to the physiological characteristics of that tree species, such as being shade intolerant, nutrient greedy and invasive.

Vegetation Diversity Index

The level of species diversity can be judged from the value of the species diversity index (H'), species dominance index (C), species richness index (R), and species evenness index (E). The values of H', R, C, and E in the core zone of the Gunung Salak I Resort are presented in Table 7.

Table 7: Diversity index values (H'), dominance (C), richness (R), and species evenness (E)

Growth Rate	H'			C			R			E		
	K1	K2	K3	K1	K2	K3	K1	K2	K3	K1	K2	K3
Understory*	2.60(s)	2.13(s)	2.77 (s)	0.09	0.16	0.09	3.79 (t)	2.58 (t)	4.59 (t)	0.88	0.83	0.87
Seedling	2.00(s)	2.16(s)	1.85(s)	0.17	0.15	0.32	2.42 (t)	2.64 (t)	4.43 (t)	0.66	0.87	0.58
Sapling	1.68(s)	1.43(r)	1.75(s)	0.20	0.32	0.24	1.76(r)	1.89(r)	2.52 (t)	0.94	0.80	0.84
Pole	1.82(s)	1.41(r)	1.91(s)	0.18	0.29	0.16	2.34 (t)	1.67(r)	2.89 (t)	0.93	0.88	0.98
Tree	1.97(s)	2.16(s)	0.90(r)	0.18	0.14	0.67	2.42 (t)	2.77(t)	2.44 (t)	0.86	0.84	0.18

*Not included in growth rate

K1: Low density class, K2: Medium density class, K3: High density class.

r: low, s: medium, t: high

Based on Table 7, the highest H' value is shown by understory in class 3 of 2.77. The lowest H' value is shown by the tree growth rate in class 3 of 0.90. H' Value in class 3 is lower than other classes because the abundance of each species does not have the same value. The value of diversity of a species can be influenced by environmental factors, such as climate, rocks, altitude and the protected status of the area.

Community with a high species diversity will have a low dominant value (C) (close to 0). The species dominance index shows the pattern of dominance of a species in a stand community (Mawazin and Subiakto 2013). The highest C value is showed by the stage tree growth in class 3. This is related to the low value of H' due to the domination of one species, namely african wood (Maesopsis eminii).

The Margalef's species richness Index (R) shows the species richness in an ecosystem (Wahyuningsih et al. 2019). According to Jorgensen et al. (2005), an ecosystem has high species richness if the index value is ≥2.05, an index value below this limit (<2.05) is categorized as low. Table 7 shows the richness of each level is generally has the high category. A community/ecosystem with a high species richness will have fewer individuals in each species.

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Species evenness index (E) shows the level of evenness of individuals per species in a certain forest area (Kusmana and Melyanti 2017; Kusmana et al 2018). The E value close to 0 indicates a low species evenness. The lowest E value was found on the tree level in class 3, comparable to the value of H'. The level of poles and stakes in all classes approaching to value of 1. This shows that the poles and stakes is relatively evenly distributed, so that the dominance ability of each species in the community is relatively balanced and the preservation of species diversity can be maintained (Dendang and Handayani 2015).

Horizontal Structure of Vegetation

The horizontal structure of forest stands describes the availability of vegetation in an ecosystem at each growth stage. The horizontal structure of forest stands is influenced by the density of the individual tree per unit area based on diameter class can be presented in Figure 3.

Figure 3 shows that the lowest density is in class 1. The resulting curve shape for the three density classes forms an inverted "J" curve. The inverted "J" curve indicates that the forest at the research location is in a balanced condition, where the higher the growth rate, the smaller the number of individuals. This shows that there is a regeneration process taking place because there is a young stage in a sufficient quantity (Dendang and Handayani 2015). The distribution of number of trees with an inverted "J" curve is generally found in tropical rainforests which describes a dynamic forest community.

However, not every species has the ability to regenerate, because of there is the possibility of changing the dominant species and natural selection that causes the reduction of the amount of individual which has survive in each diameter class. The regeneration process is crucial in the forest ecosystem to continue forest succession. Natural regeneration occurs naturally from seedlings, saplings, poles, and trees. It plays a crucial role in shaping the forest stand structure and species composition (Istomo et al 2023; Damayanti et al. 2017).

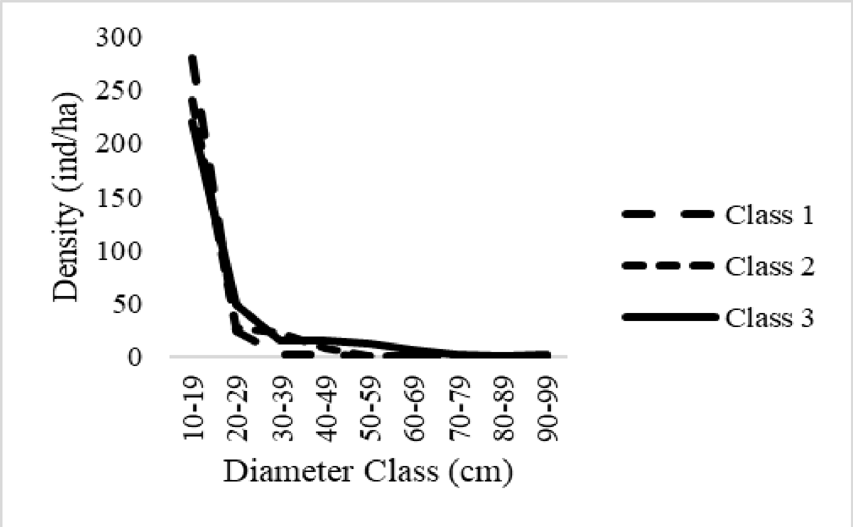

Figure 3: Distribution of individuals by diameter class

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Biomass and Carbon Stock Estimation

Biomass is mass that comes from living things, including living organic material and dead organic material. Forest standing biomass is divided into above-ground biomass and below-ground biomass. The results of biomass and carbon stock estimation in the core zone of TNGHS are presented in Table 8. IPCC (2006) states that vegetation biomass or organic material in forests contains the element carbon (C) at a concentration of 47%. Based on Table 8, the estimated value of biomass and carbon stocks increases with increasing vegetation density. The highest biomass and carbon stock are shown by class 3, for each 888.907 tones/ha and 417.786 tones C /ha, respectively. Based on its part, the aboveground biomass (AGB) contributed greatly to the total biomass, at 80.1%. The highest AGB is found in the stem part at 55.5% of the total biomass, followed by the branches part at 17.4%, the leaves at 4.9%, and the smallest biomass at the stem at 2.4% (Yusuf et al. 2014).

Tuah et al. (2017) stated that carbon stocks at a location or plot are influenced by the vegetation density of the plot as well as the diameter and age of the trees. Biomass potential and carbon stock based on the class density have an average value of 124.46 tones/ha and 58.50 tones/ha. Previous research by Hakim et al. (2021) in the Liang Anggang Protected Forest area, biomass and carbon reserve values were 21.39 tons/ha and 10.05 tons/ha. Results obtained higher compared to research by Hartoyo et al. (2022) in the TNGHS traditional zone. From this research, the biomass and carbon concentration values were obtained at 108.55 tones/ha and 51.02 tones/ha.

Table 8: Top biomass and carbon stocks stands in various density classes

Class density	Level growth	Biomass(ton/ha)	Carbon reserves(ton C/ha)
Low (K1)	Understory[a] and	0.19	0.19
	Seedling		
	Sapling	31.31	14.72
	Pole	20.83	9.79
	Tree	30.96	14.55
Sub-Total		83.29	39.15
Currently (K2)	Tree	30.96	14.55
	Seedling		
	Sapling	20.36	9.57
	Pole	29.00	13.63
	Tree	60.70	28.53
Sub-Total		110.34	51.86
Tall (K3)	Understory[a] and	0.21	0.10
	Seedling		
	Sapling	20.07	9.43
	Pole	10.19	4.79
	Tree	149.27	70.16
Sub-Total		179.74	84.48
Total		373.37	175.49
Average		124.46	58.50

*Not included in growth rate

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Table 9: *Pearson* correlation test

Variable	Number of types	Tree density (ind/ha)	Shannon-Wiener Index	BA (m^2/ha)	Carbon concentration (ton C/ha)
Tree density	0.908**	-	-	-	-
Shannon-Wiener Index	0.645**	0.564*	-	-	-
BA (m^2/ha)	0.746**	0.671**	0.429	-	-
Carbon concentration	0.426	0.405	0.220	0.857**	-
NDVI	0.644**	0.518*	0.520*	0.872**	0.689**

* Correlation is significant at the 0.05 level (2-tailed), ** Correlation is significant at the 0.01 level (2-tailed).

The different biomass and carbon stock values in each TNGHS zone are due to differences in environmental conditions and vegetation that make up the zone's ecosystem. This is in accordance with the statement (Tuah et al. 2017) that carbon stocks at a location or plot are influenced by the vegetation density of the plot as well as the diameter and age of the trees.

Relationship between NDVI and Number of Species, Number of Individuals, Shannon - Wiener Index, BA, and Carbon Concentration

Pearson correlation test is a parametric statistical test that uses interval and ratio data with certain requirements, namely that it must meet the classical assumption test (normality and heteroscedasticity) (Purba and Purba 2022). The results of the Pearson correlation test are presented in (Table 9). The Pearson correlation test is used to measure the closeness of the relationship between two variables, namely the independent variable and the dependent variable. Based on Table 9, the correlation between carbon concentration and LBDS has a positive coefficient value, namely 0.857. This is in accordance with the statement by Yusuf et al. (2014) that 55.5% of the biomass in the stand is stored in the stems. A positive correlation relationship with a high coefficient value is also indicated by tree density and number of species. This is in accordance with the statement of Arifanti et al. (2014) that submontane forests are rich in various types trees and has a high density.

Based on the assumed calculated r value, the results of the correlation test between NDVI and all dependent variables are stated to be correlated with each other. The NDVI value has the highest correlation with LBDS (m2 /ha), namely (0.872), while LBDS is strongly correlated with carbon concentration. This indicates that NDVI is directly correlated with carbon concentration via BA. This is in line with research by Siregar (2018) which states that the relationship between LBDS and NDVI has a positive value, where the higher the NDVI, the higher the value of BA. A regression test was carried out to confirm and determine to what extent the NDVI value as an independent variable can explain or predict the number of species, tree density, Shannon-Wiener index, BA, and carbon concentration as the dependent variable. The results of the regression analysis (Figure 4) show that the largest coefficient of determination was found in the BA variable at 78.26%. This shows that BA can explain NDVI of 78.26%. According to Bachtiar et al. (2022) the coefficient of determination in the value range of 60-79.9% is included in the strong interpretation category. The analysis results

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obtained are in line with research by Rahmatulloh (2021), in Gunung Leuser National Park with a coefficient of determination between NDVI and BA of 64.69%.

Validation of the estimation model is carried out to see and determine the accuracy of the resulting estimation model. The results of the validity test of the 5 parameters estimation model are presented in Table 10.

Table 10: Test the validity of the estimation model

Parameter	Model	Validity
Number of types	y = 310.76x - 67.358	0.00003 %
Tree density	y = 148.62x - 31.558	0.00225 %
Shannon-Wiener Index	y = 6.1312x + 0.5765	0.00101 %
BA	y = 39.261x - 9.993	0.00008 %
Carbon concentration	y = 678.67x - 148.07	0.00074 %

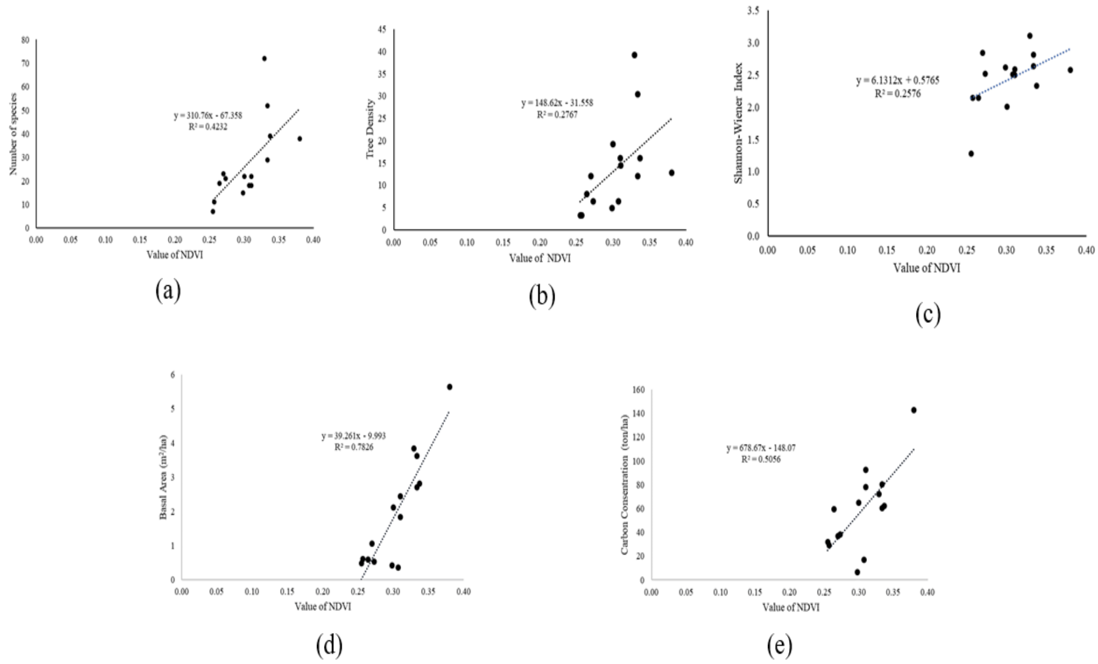

Figure 4: Relationship between NDVI values and observation variables. NDVI with number of species (a), NDVI with tree density (b), NDVI with Shannon-Wiener index (c), NDVI with BA (d), NDVI with carbon concentration (e)

The validity test results in (Table 10) show that the validity value is below 1%. Muhammad (2014) stated that the accuracy of the model is shown by the results of the validity test which has a small percentage value. This statement is in line with Rahmatulloh (2021) that the estimation model taken is the estimation model with the smallest validity value, because the smaller the percentage value, the more accurate the model will be. This shows that the five estimation models for determining the number of species, tree density, Shannon-Wiener index, LBDS, and carbon concentration have high accuracy.

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CONCLUSIONS

NDVI analysis produces 3 classes of vegetation density, namely class 1 (low density) with a value of 0.147 - 0.276, class 2 (medium density) with a value of 0.276 - 0.321, and class 3 (high density) with a value of 0.321 - 0.493. The TNGHS core zone consists of 82 plant species from 53 families. The most commonly found families are Euphorbiaceae, Lauraceae, Moraceae, Rubiaceae and Urticaceae. The dominant stand type is African wood (*Maesopsis eminii*). The horizontal structure of vegetation in all classes forms an inverted "J" curve which shows that individual distribution can guarantee forest sustainability due to the availability of regeneration (1). The average biomass and carbon concentrations obtained were 124.46 tonnes/ha and 58.50 tonnes/ha respectively (2). Carbon concentration is strongly correlated with NDVI values (r = 68.9%). NDVI values can be used to estimate carbon stocks (3). Mount Halimun Salak National Park has great potential in efforts to mitigate CO_2 gas emissions through increasing carbon stock. Information regarding carbon storage in TNGHS is still very limited, so research needs to be carried out regarding carbon storage in resorts and other zones in TNGHS.

References

1) Arifanti VB, Dharmawan IWS, Wicaksono D. 2014. Potential carbon reserves of sub-montane forest stands in Mount Halimun Salak National Park. *Journal of Forestry Social and Economic Research.* 11(1):13-31. DOI: https://doi.org/10.20886/jpsek.2014.11.1.13-31.

2) Bachtiar YS, Harisuseno D, Sidqi J, Fidari F. 2022. Prediction of infiltration rate based on soil porosity, distribution of sand grains and silt. *Journal of Water Resources Technology and Engineering.* 2(1):156-168. DOI: https://doi.org/10.21776/ub.jtresda.

3) Banuwa IS, Afriliyanti R, Utomo M, Yusnaini S, Riniarti M, Sanjaya P, Suroso E, Hidayat W. 2019. Short Communication: Estimation of the above- and below-ground carbon stocks in University of Lampung, Indonesia. *Biodiversitas* 20: 676-681. DOI: https://doi.org/10.13057/biodiv/d200309.

4) [BTNGHS] Balai Taman Nasional Gunung Halimun Salak. 2021. *Statistik Balai Taman Nasional Gunung Halimun Salak Tahun 2020*. Sukabumi: Balai Taman Nasional Gunung Halimun Salak.

5) Chave J, Andalo C, Brown S, Cairns MA, Chambers JQ, Eamus D, Folster H, Fromard F, Higuchi N, Kira T, *et al.* 2005. Tree allometry and improved estimation of carbon stocks and balance in tropical forests. *Oecologia.* 145:87-99. DOI: 10.1007/s00442-005-0100-x.

6) Dahlana MM, Istomo I, and Wibowo C. 2018. Structure and Distribution of Rasamala (*Altingia excelsa* Noronha) and Jamuju (*Dacrycarpus imbricatus* Blume de Laub.) in Gunung Gede Pangrango National Park. Case Study of Cimande and Selabintana Resort. *International Journal of Sciences: Basic and Applied Research* (IJSBAR) 40 (1): 1-14. URL: https://www.gssrr.org/index.php/JournalOfBasicAndApplied/article/view/8453/4064.

7) Damayanti DR, Bintoro A, dan Santoso T. 2017. Natural Regeneration Forest National Park Management Unit (NPMU) Region III Kuala Penet Way Kambas National Park. Jurnal Sylva Lestari 5(1):92-104. DOI: http://dx.doi.org/10.23960/jsl1592-104.

8) Dendang B, Handayani W. 2015. Structure and composition of forest stands in Gunung Gede Pangrango National Park, West Java. *Pros Sem Nas Masy Biodiv Indon*. 1(4): 691-695. DOI: 10.13057/psnmbi/m010401.

DOI: 10.5281/zenodo.13064534

9) Dewanto BEB, Jatmiko RH. 2021. Estimation of Aboveground Carbon Stock Using Sar Sentinel-1 Imagery In Samarinda City. *International Journal of Remote Sensing and Earth Sciences* 18(1): 103-116. DOI: http://dx.doi.org/10.30536/j.ijreses.2021.v18.a3609

10) Febiriyanti A *et al.* 2021. Estimation of carbon stocks from tree stands vegetation in Universitas Indonesia's urban forest, Depok *J. Phys.: Conf. Ser.* 1725 012043. DOI 10.1088/1742-6596/1725/1/012043

11) Hartoyo APP, Khairunnisa S, Pamoengkas P, Solikhin A, Supriyanto, Siregar IZ, Prasetyo LB, Istomo I. 2022. Estimating carbon stocks of three traditional agroforestry systems and their relationships with tree diversity and stand density. *Biodiversitas.* 23(12):6137-6146. DOI: https://doi.org/10.13057/biodiv/d231207

12) Hidayat D, Hardiansyah G. 2012. Study of the diversity of medicinal plant species in the PT IUPHHK area. Sari Bumi Kusuma Camp Tontang, Sintang Regency. *Vokasi*. 8(2): 61-68.

13) [IPCC] Intergovernmental Panel on Climate Change. 2006. *IPCC Guidelines for National Greenhouse Gas Inventories*. Hayama (JP): Inst for Global Environmental Strategies.

14) Istomo, Kusmana, C., & Naibaho, B.D. 2017. Biomass potential on several mangrove planting models in Java Island, Indonesia. *AACL Bioflux* 10 (4):754 – 767. DOI:

15) Istomo, Kusmana C, Dwiyanti FG, Malik D. 2020. Comparison of several methods of stands inventory prior to logging towards the yield volume of mangrove forest in Bintuni Bay, West Papua Province, Indonesia. *Biodiversitas* 21: 1438-1447. DOI: https://doi.org/10.13057/biodiv/d210423

16) Istomo I, and Armila N. 2023. Distribution Pattern of Pasang Species (*Quercus sundaica* Blume) in Mount Slamet Forest, East Banyumas Forest Management Unit. *Forestry Science Journal*, 17(1), 85-95. https://doi.org/10.22146/jik.v17i1.5176.

17) Jørgensen SE, Costanza R, Xu FL. 2005. *Handbook of Ecological Indicators for Assessment of Ecosystem Health.* Boca Raton (US): CRC Pr

18) Kusmana C, Melyanti AR. 2017. Diversity of vegetation type composition and structure in protected forest areas with the PBHM pattern at BKPH Tampomas, KPH Sumedang, Perum Perhutani Regional Division of West Java and Banten. *Jurnal Manusia dan Lingkungan*. 22(2): 151-159. DOI: https://doi.org/10.29244/j-siltrop.8.2.123-129.

19) Kusmana C, Hidayat T, Tiryana T, Rusdiana O, Istomo I, 2018. Allometric models for above- and below-ground biomass of Sonneratia spp., *Global Ecology, and Conservation.* Vol. 15, DOI: https://doi.org/10.1016/j.gecco.2018.e00417.

20) Muhammad A. 2014. Mapping changes in forest canopy density in KPH Kuningan [Undergraduate Thesis]. Bogor: IPB University.

21) Mosa SA. 2023. Estimation of vegetation density using NDVI and carbon stocks in the utilization zone of Mount Halimun Salak National Park [Undergraduate Thesis]. Bogor: IPB University.

22) Novarianto MA. 2017. Estimation of above-ground biomass in mixed stands [Undergraduate Thesis]. Bogor (ID): IPB University.

23) Purba D, Purba M. 2022. Application of correlation and regression analysis using Pearson Product Moment and Simple Linear Regression. Science Technology Image. 1(2):97-103. DOI: https://doi.org/10.2421/cisat.v1i2.54.

24) Rahmatulloh R. 2021. Analysis of stand composition and structure with NDVI in Gunung Leuser National Park, Aceh Province. Bogor: IPB University.

25) Sari PN. 2017. Distribution and habitat characteristics of rasamala (*Altingia excelsa* Noronha) in Mount Halimun Salak National Park. [Undergraduate Thesis]. Bogor: IPB University.

ISSN 1533-9211

DOI: 10.5281/zenodo.13064534

26) Siregar HI. 2018. Analysis of Changes in Vegetation Density in Coastal Villages, Central Tapanuli Regency and Sibolga City Using Landsat Imagery. [Undergraduate Thesis]. Medan: Universitas Sumatera Utara.

27) Suwargana N. 2013. Spatial, temporal and spectral resolution of Landsat, SPOT and Ikonos satellite images. *Jurnal Ilmiah WIDYA*. 1(2): 167-174.

28) Tuah N, Sulaeman R, Yoza D. 2017. Calculation of above-ground biomass and carbon in the Rumbio Traditional Prohibited Forest, Kampar District. *JOM Faperta UR*. 4(1):1-10.

29) Yurianda RB, Setyawan D, Warsito. 2022. Normalized Difference Vegetation Index classification method based on Landsat 8I imagery to identify the distribution of health conditions of oil palm plants at PT. Andira Agro, South Sumatra. *Journal of Soil Science and Land Resources*. 8(2):15-24. DOI: http://dx.doi.org/10.26418/pedontropika.v8i2.56431

30) Yusuf M, Sulistyawati E, Suhaya Y. 2014. Biomass Distribution Above and Below the Surface of Surian (*Toona Sinensis* Roem). *Journal of Mathematics and Science*.19(2):69-75.